ENDOGENOUS POWER AND HEAT GENERATION MODELLING IN VARIOUS CHP PLANT TYPES

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Overview

Combined heat and power (CHP) generation, also known as cogeneration, achieves significantly higher fuel use efficiencies of 80 to 90% compared to an uncoupled generation of power and heat. In various countries' energy policies it is considered therefore as a highly efficient and environmentally friendly technology to meet power and heat demands, since it helps reducing primary energy consumption and CO_2-emissions in the energy sector (IEA, 2009). There exists a wide variety of CHP plant types, which differ in terms of fuel use, marginal costs, CO_2-emissions or the coupling of power and heat output (AGFW, 2011). The latter highly depends on the plant's design configutration. However, single sector models, such as ELMOD (Leuthold et al., 2012), abstract from the variety of CHP plant types existing in the market and the constraints resulting from these different design configurations, since they focus at only one energy sector. Most electricity models use a simplified exogenous approach assigning minimum power output levels to the CHP generators in their power system. Approaches in the past to model CHP generators in more detail have been made by Yusta et al. (2008) and Cho et al. (2009), who focus on the management perspective of a certain CHP plant acting in a liberalized power market for a make-or-buy decision. Other approaches, such as of Gardner and Scott Rogers (1997), took a power system optimization view, but accounted only for a single type of CHP plant. The idea of this paper is to develop a more sophisticated approach to CHP modelling and thus, to better inform about the potential power and heat interaction at a power system level.

Methods

In order to account for the bivalent nature of the power and heat sector linking CHP plants, the paper presented here proposes a modelling technique, in which each demand is met endogenously by allocating every plant's fuel input to the possible power and heat output in a cost minimizing way. The modelling challenge faced herewith is to regard on the one hand the diversity of CHP technologies and on the other hand to consider the efforts and limited information about plant parameters in real world systems. The diversity is captured by using six stylized CHP types, which are steam cycle plants with either back-pressure steam turbine with and without heat bypass or extraction-condensation steam turbine as well as combined cycle plants with either back-pressure or extraction-condensation steam turbine and simple gas turbines with heat recovery boiler. Describing these common types by means of a limited set of parameters the paper provides a comprehensive modelling technique that can be easily extended.

This endogenous modelling approach is juxtaposed to the commonly applied exogenous approach as well as to the method applied by the German Power Grid Development Plan 2015 (50Hertz et al., 2015) in order to analyse deviations in the dispatch and operational costs. This comparison serves to show if the endogenous approach can be justified with more accurate results. Furthermore this comparison is extended to the variation with heat storages attached to CHP plants.

The method is implemented in a cost minimizing power system unit-commitment model, where all plants contribute to cover a common residiual power load. In addition to electricity, CHP plants also generate heat to fullfill an individual heat demand. There could be also several CHP plants covering a common heat demand in conjunction, at first however, they are kept separate here in order to better analyse each CHP type individually. The model is solved as a mixed integer problem (MIP) applying GAMS (General Algebraic Modeling System). To maintain comparability between the different modelling approaches the same data set is used in each case.

Expected Results

The comparision between the endogenous, the simple exogenous approach and the method applied by the German Grid Development Plan 2015 shows significant deviations in terms of amounts of coupled power generation and operational costs. The magnitude of the deviation differs with the distinct CHP types. These differences decrease through the implementation of heat storages attached to CHP plants.

Expected Conclusions

It is expected to find that the size of the deviations is linked to the flexibility of each CHP technology. Less flexible plants, that is CHP types with a stricter coupling of power and heat output, show higher deviations in the exogenous approach compared to the endogenous approach. The more a power system contains unflexible CHP plants, the higher will be the difference between modelling coupled power generation exogenously or endogenously. Consequently the deviations decrease with an increasing degree of flexibility in the system. Especially by considering heat storages the CHP plants become more flexible and the deviations become less important.

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